# Studying the Rigidity

To increase the positioning accuracy of feed screws in NC machine tools or the precision machines, or to reduce the displacement caused by the cutting force, it is necessary to design the rigidity of the components in a well-balanced manner.

## Axial Rigidity of the Feed Screw System

When the axial rigidity of a feed screw system is K, the elastic displacement in the axial direction can be obtained using the equation (36) below.

$$\delta = \frac{Fa}{K} \quad \cdots\cdots\cdots(36)$$

δ : Elastic displacement of a feed screw system in the axial direction (μm)
Fa : Applied axial load (N)

The axial rigidity (K) of the feed screw system is obtained using the equation (37) below.

$$\frac{1}{K} = \frac{1}{K_S} + \frac{1}{K_N} + \frac{1}{K_B} + \frac{1}{K_H} \quad \cdots\cdots\cdots(37)$$

K : Axial Rigidity of the Feed Screw System (N/μm)
$K_S$ : Axial rigidity of the screw shaft (N/μm)
$K_N$ : Axial rigidity of the nut (N/μm)
$K_B$ : Axial rigidity of the support bearing (N/μm)
$K_H$ : Rigidity of the nut bracket and the support bearing bracket (N/μm)

**[Axial rigidity of the screw shaft]**

The axial rigidity of a screw shaft varies depending on the method for mounting the shaft.

### ● For Fixed-Supported (or -Free) Configuration

$$K_S = \frac{A \cdot E}{1000 \cdot L} \quad \cdots\cdots\cdots(38)$$

A : Screw shaft cross-sectional area ($mm^2$)

$$A = \frac{\pi}{4} d_1^2$$

$d_1$ : Screw-shaft thread minor diameter (mm)
E : Young's modulus ($2.06 \times 10^5$ N/$mm^2$)
L : Distance between two mounting surfaces (mm)

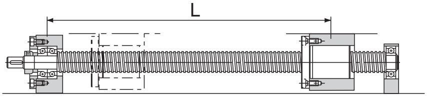



Fig.16 on A15-52 shows an axial rigidity diagram for the screw shaft.

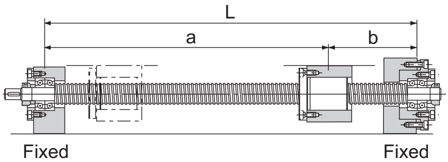
## ● For Fixed-Fixed Configuration

$$K_s = \frac{A \cdot E \cdot L}{1000 \cdot a \cdot b} \quad \cdots\cdots\cdots(39)$$

Ks becomes the lowest and the elastic displacement in the axial direction is the greatest at the position of $a = b = \frac{L}{2}$.

$$K_s = \frac{4A \cdot E}{1000L}$$

Fig.17 on A15-53 shows an axial rigidity diagram of the screw shaft in this configuration.



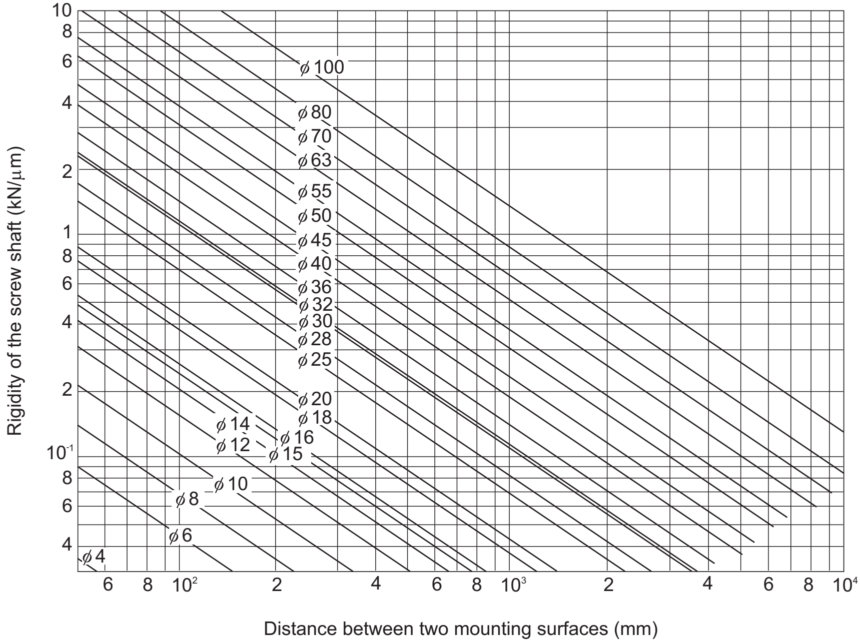




Fig.16 Axial Rigidity of the Screw Shaft (Fixed-Free, Fixed-Supported)

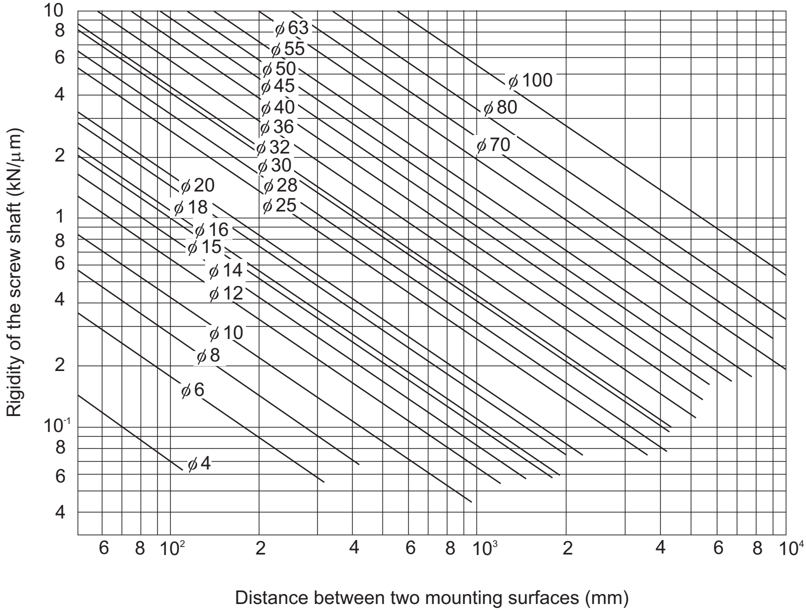



Fig.17 Axial Rigidity of the Screw Shaft (Fixed-Fixed)

## [Axial rigidity of the nut]

The axial rigidity of the nut varies widely with preloads.

### ● No Preload Type

The logical rigidity in the axial direction when an axial load accounting for 30% of the basic dynamic load rating (Ca) is applied is indicated in the specification tables of the corresponding model number. This value does not include the rigidity of the components related to the nut-mounting bracket. In general, set the rigidity at roughly 80% of the value in the table.

The rigidity when the applied axial load is not 30% of the basic dynamic load rating (Ca) is calculated using the equation (40) below.

$$K_N = K\left(\frac{Fa}{0.3Ca}\right)^{\frac{1}{3}} \times 0.8 \quad \cdots\cdots\cdots(40)$$

$K_N$ : Axial rigidity of the nut (N/μm)

K : Rigidity value in the specification tables (N/μm)

Fa : Applied axial load (N)

Ca : Basic dynamic load rating (N)

## ● Preload Type

The logical rigidity in the axial direction when an axial load accounting for 10% of the basic dynamic load rating (Ca) is applied is indicated in the dimensional table of the corresponding model number. This value does not include the rigidity of the components related to the nut-mounting bracket. In general, generally set the rigidity at roughly 80% of the value in the table.
The rigidity when the applied preload is not 10% of the basic dynamic load rating (Ca) is calculated using the equation (41) below.

$$K_N = K\left(\frac{Fa_0}{0.1Ca}\right)^{\frac{1}{3}} \times 0.8 \quad \cdots\cdots\cdots(41)$$

$K_N$ : Axial rigidity of the nut (N/μm)
K : Rigidity value in the specification tables (N/μm)
$Fa_0$ : Applied preload (N)
Ca : Basic dynamic load rating (N)

### [Axial rigidity of the support bearing]

The rigidity of the Ball Screw support bearing varies depending on the support bearing used.
The calculation of the rigidity with a representative angular contact ball bearing is shown in the equation (42) below.

$$K_B \doteqdot \frac{3Fa_0}{\delta a_0} \quad \cdots\cdots\cdots(42)$$

$K_B$ : Axial rigidity of the support bearing (N/μm)
$Fa_0$ : Applied preload of the support bearing (N)
$\delta a_0$ : Axial displacements (μm)

$$\delta a_0 = \frac{0.45}{\sin\alpha}\left(\frac{Q^2}{Da}\right)^{\frac{1}{3}}$$

$$Q = \frac{Fa_0}{Z\sin\alpha}$$

Q : Axial load (N)
Da : Ball diameter of the support bearing (mm)
α : Initial contact angle of the support bearing (°)
Z : Number of balls
For details of a specific support bearing, contact its manufacturer.

### [Axial Rigidity of the Nut Bracket and the Support Bearing Bracket]

Take this factor into consideration when designing your machine. Set the rigidity as high as possible.